SSERVI-ESF14-124

Author: JAMES BURKE

POSTER

Human Exploration

HUMAN LUNAR SURFACE SCIENCE--PLANT GROWTH

Sustainable plant growth will be vital to lunar settlement, not only for human life support but also for many other uses. Much of the needed scientific and engineering knowledge is absent today. Earth-based and ISS demonstrations are essential. Robotic lunar surface experiments are the logical next step, but ultimately human-supervised, large-scale, long-duration proof tests must occur before any commitment to permanent dependence on lunar agriculture and forestry. Here we intend to describe and advocate small-scale activities that can begin now, as part of the GER roadmap's human lunar surface mission preparations, to advance world space development toward the goal of realistic reliance on plants grown on the Moon.

Author: BRENT BARBEE

ORAL

Human Exploration and Destination Drivers

The Near-Earth Object Human Space Flight Accessible Targets Study (NHATS)

The Near-Earth Object Human Space Flight Accessible Targets Study (NHATS) is an ongoing collaborative effort conducted by the NASA Goddard Space Flight Center (GSFC) and Jet Propulsion Laboratory (JPL). The objective of the NHATS system is to automatically monitor the near-Earth asteroid (NEA) population for round-trip mission accessibility in the context of potential future Human Space Flight (HSF) missions. The NHATS began in September 2010 under the auspices of NASA Headquarters Planetary Science Division of the Science Mission Directorate in cooperation with the Advanced Exploration Systems Division of the Human Exploration and Operations Mission Directorate. Automation of the NHATS system was completed on March 20, 2012 and the system has been operating continuously since then.Each day the automated NHATS system creates a list of NEAs newly added to the JPL Small-Body Database (SBDB) and NEAs with updated orbit solutions, and then applies the method of embedded trajectory grids to precise ephemerides for those NEAs, obtained via the JPL Horizons system. The results map out available round-trip mission opportunities to the NEAs between the years 2015 and 2040, with trajectory constraints enforced such that NEAs offering at least one round-trip mission solution meeting the constraints (e.g., total mission change-in-velocity less than 12 km/s, mission duration less than 450 days, and others) are more dynamically accessible than Mars. The daily results are automatically loaded into the NHATS web-site database and a summary email is transmitted to all NHATS mailing list subscribers. At present, 1180 of the currently known 10763 NEAs satisfy NHATS constraints and are, therefore, referred to as NHATS-compliant. The NHATS system also computes the next available optical and radar observation opportunities for all the NHATS-compliant NEAs as an aid to observers. NEAs are discovered almost daily, and often the time just after discovery is also the optimal time to provide follow-up observations to better estimate their orbits and characterize their physical nature. These follow-up observations are particularly important for those NEAs that could become potential future mission targets. Hence, it is prudent to monitor NEA discoveries daily and run an analysis to determine if any among them warrant additional study, as they might become attractive mission targets.In this talk we will provide an overview of the automated NHATS system and describe key characteristics of the NHATS-compliant segment of the NEA population, including orbital element distributions and relationships between accessibility metrics (e.g., change-in-velocity, mission duration) and NEA physical/orbital characteristics (e.g., absolute magnitude, synodic period). We will also show examples of NHATS-compliant NEAs for which follow-up observations were obtained after the NHATS system provided notification. Finally, we will place the round-trip HSF mission accessibility of the NHATS-compliant NEAs into context by comparing their accessibility to that of other destinations including lunar orbits, the lunar surface, Mars orbits, the martian moons Phobos and Deimos, and the martian surface.

Author: JACOB BLEACHER

Human Exploration and Destination Drivers

ORAL

Geologist Crew Assignments During Delayed Communication Human Exploration of Solar System Surfaces

The 2011 Desert RATS field test simulated human scientific exploration of a Near Earth Asteroid. Test conditions involved 3 or 4 human crewmembers operating from prototype Space Exploration Vehicles (SEVs) and/or the Deep Space Habitat (DSH), command station, assumed to be in orbit around the target. Extra Vehicular Activities (EVAs) could begin from the DSH or the SEV. A 50-second one-way communication delay between the crew and Mission Control Center (MCC) and Science Support Room (SB) was introduced in this test. Internal Vehicular (IV) crewmembers were located inside the SEV, DSH or both, and experienced no time delay with EVA crew. The time delay made it impractical to carry on voice conversations with MCC and SB, and the crew adapted to depend on themselves for tactical science decisions. This situation placed increased responsibility on the crew geologists to perform the role of field science "PI". As a result, the position assignment of the crew geologists within the test produced intriguing results.In order to simulate microgravity, we tested two EVA modes of operation. One involved a theoretical self-contained propulsive backpack dubbed the "Super" SAFER (Simplified Aid For EVA Rescue). This capability enabled the crewmember to conduct an un-tethered EVA, but required anchoring to the surface and involved constraints on the number of allowable starts and stops to simulate propellant use. The second EVA mode involved the Astronaut Positioning System (APS), a simulated "robotic" arm that was attached to the fore of the SEV. The EVA crewmember controlled their position on the APS, while the SEV maintained position around the target. The APS constrained operational radius of the EVA crewmember, beyond which required a translation of the SEV.Prior to the test most participants expected that the best position for a geologist would be in an EVA role. However, test results showed that using a geologist in the IV position held distinct advantages. All crewmembers identified the IV position as extremely important during delayed communications operations. The IV role enabled a crewmember to access science files related to the tasks at hand, or past tasks, which were not available to EVA crewmembers. Furthermore, the IV crewmember had access to each EVA crewmembers data in real-time, enabling comparisons. Thus, assigning a geologist to the IV role enabled this crewmember to provide scientific situational awareness to the team on the surface when this input was lacking from the SB due to communication delay. Additionally, sample collection protocols are time-consuming. An IV geologist located in the SEV, in close proximity with the EVA crew, had the ability to plan subsequent science tasks while the EVA crew completed sample and site documentation. This essentially enabled "expertise multiplication" in much the same way that professional geologists work with field assistants. Because these results differ from our expected results we conclude that future exploration strategies that include an IV role require further field testing.

Author: SARAH BRADEN

ORAL

Human Exploration and Destination Drivers

Irregular Mare Patches as Lunar Exploration Targets

Irregular Mare Patches as Lunar Exploration Targets. *S. E. Braden, M. S. Robinson, J. D. Stopar, S. J. Lawrence. (*sebraden@asu.edu) Irregular Mare Patches (IMPs) are small, morphologically distinct, basaltic features within the nearside lunar maria. More than 75 separate IMPs greater than 100 m in largest dimension are known [1-4]. Several IMPs have model ages of 18-58 Ma (from crater counting) [4], which is significantly later than the last phase of lunar mare basalt volcanism (1-1.2 Ga) [e.g. 5-7]. Morphologic and stratigraphic comparisons with other young lunar features provide an additional age constraint of <100-200 Ma [4]. The existence of young IMPs suggests long-lived nearside magmatism, which is a key constraint on lunar thermal evolution. Thermal models must provide enough interior energy to allow for low volume eruptions on the surface well into the Copernican period. As potential examples of some of the youngest volcanic material, IMPs are high priority targets for future lunar exploration.Confirmation of the young model ages through sample return would not only verify young basaltic volcanism on the lunar nearside but also provide new information on lunar magmatic evolution, while confirming methods for deriving estimated ages from crater counting on young surfaces, as well as adding to our knowledge of space weathering processes, regolith production, and the rate of erosive processes over relatively short lunar timescales (100 Ma). A large IMP would make a scientifically rewarding and exciting landing site for robotic or human exploration. For example, Ina (18.65°N, 5.30°E, 3 km) within Lacus Felicitatis, has high-resolution LROC Narrow Angle Camera [8] digital terrain models (~2 m/pixel), which enable detailed mission planning and hazard analysis, as previously demonstrated by [9, 10]. Images from the surface documenting any exposed outcrops and flow fronts will help to clarify the processes involved in the formation of IMPs. Additionally, IMPs are visually compelling exploration targets that showcase a unique and different view of the Moon, which has the potential to significantly engage the public. [1] Whitaker, E.A., 1972. NASA SP-289, p.25-84 to 25-85. [2] Schultz, P.H., 1976. Moon Morphology, 626 pp. [3] Stooke, P.J., 2012. LPS, 43, abstract 1011. [4] Braden, S.E., PhD Dissertation, Arizona State University, December, 2013. [5] Schultz, P.H., Spudis, P.D., 1983. Nature 302, 233-236. [6] Hiesinger H., et al., 2003. J. Geophys. Res. 108, 5065. [7] Hiesinger, H., et al., 2011. GSA Special Papers 477, 1-51. [8] Robinson, M.S., et al., 2010. Space Sci. Rev. 150, 81-124. [9] Braden, S.E., Robinson, M.S., 2011. GSA Special Papers 483, 507-518. [10] Lawrence et al. 2014 LPSC 45 2014 Abstract 2785.

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Author: BEN BUSSEY

ORAL

Human Exploration and Destination Drivers

New Analyses of the Moon's North Polar Illumination Conditions

We continue to enhance our LunarShader illumination simulation capability. This tool accurately determines the surface illumination conditions given a topography file and a selected date/time. Recent improvements includeWe have analyzed the Moon's north polar region using LunarShader and recent high-resolutions Digital Elevation Models. We have determined which sites receive the most illumination and then for those sites we fully characterize the illumination conditions. This analysis includes deriving several parameters of interest when planning either a lunar lander or rover mission. Examples of such parameters include:-1. Longest single period of continuous illumination2. Longest single period of constant shadow3. Mean amount of illumination4. Areas receiving no illumination (permanently shadowed)5. Earth-visibility mapsEach of these parameters is useful for different types of mission…1. Regions which have the longest single period of constant illumination, centered on mid-summer, are of interest for lander missions that want as long a duration as possible but are not designed to survive a lunar night. Analyses of the polar regions have revealed that locations exist that are continuously illuminated for several months.2. For extremely long surface missions, i.e. multiple years, a key parameter is the longest single period of constant shadow. This can determine the battery mass that is required to provide enough energy to heat key components. If the lander can survive the longest shadow it should be able to survive the whole year, so long as there is enough time to recharge once the longest shadow period ends before the next period begins.3. The mean amount of illumination simply shows the percentage of time that a point on the surface is illuminated. We have known for sometime that places exist that are illuminated for over 70% of the time during a winter day and 100% of a summer day. Often this type of study is undertaken to identify which locations to do detailed illumination studies on.4. Areas that receive no illumination, i.e. are permanently shadowed are known to be extremely cold and can harbor volatile deposits. Analysis of LOLA topography revealed that permanent shadow can exist at latitudes as low as 58°.5. LunarShader can also determine whether a location can see the Earth at a particular time. This is key information for either a lander or rover that will use Direct To Earth (DTE) communications rather than a relay communication satellite. sAdditionally we have developed to ability to determine when a lander is in line of sight of a deployed rover. This is useful for the mission scenario where the rover requires a lander for high data rate communications with Earth.

Author: JULIE CASTILLO-ROGEZ

Human Exploration and Destination Drivers

POSTER

Overview of a Preliminary Destination Mission Concept for a Human Orbital Mission to the Martian Moons

Introduction: The National Aeronautics and SpaceAdministration's Human Spaceflight ArchitectureTeam (HAT) has been developing a preliminary DestinationMission Concept (DMC) to assess how a humanorbital mission to one or both of the Martian moons,Phobos and Deimos, might be conducted as a followonto a human mission to a near-Earth asteroid (NEA)and as a possible preliminary step prior to a humanlanding on Mars. The HAT Mars-Phobos-Deimos(MPD) mission also permits the teleoperation of roboticsystems by the crew while in the Mars system. TheDMC development activity provides an initial effort toidentify the science and exploration objectives andinvestigate the capabilities and operations conceptsrequired for a human orbital mission to the Mars system.In addition, the MPD Team identified potentialsynergistic opportunities via prior exploration of otherdestinations currently under consideration. Activity Goal: The primary goal of the activitywas to determine whether an opposition-class mission(short-stay mission of ~30-90 days at Mars) providessufficient time to meet all or most of the science andexploration objectives at Phobos and Deimos, or if aconjunction-class mission (long-stay mission of ~450-540 days at Mars) is required. Study Areas: This presentation will provide a briefoverview of the HAT MPD activity, including discussionsof the following seven study areas that were investigated:1) science objectives and requirementsformulation; 2) exploration objectives and requirementsformulation; 3) destination activity implementationstrategy; 4) mission implementation strategy; 5)synergies with cis-lunar activities; 6) synergies withhuman and robotic precursor missions to NEAs; 7)robotic precursor requirements for a human mission toMars orbit and its moons. Activity Conclusions: Preliminary results fromthe MPD activity indicate that a meaningful humanorbital mission to explore both Martian moons androbotically retrieve a MSR cache from low Mars orbitcould be performed during an opposition-class missionopportunity. The initial destination mission plan indicatesthat 56 days are required to accomplish all scienceand exploration objectives. Margin and missionreduction opportunities provide confidence that a successfuland worthwhile mission could be completedwithin 60-90 days in the Mars system. Preliminaryparametric based estimates of the expected initial massin low-Earth orbit (IMLEO) for a transportation architectureutilizing nuclear thermal propulsion to supportan opposition-class mission (total duration of approximately550 days) range from 350 to over 1000 metrictons. The IMLEO is highly dependent on the Marsdeparture opportunity, with 2033 offering a minimumin the 2030-2040 timeframe. Detailed mass sizing andvolumetric analyses are needed to validate these initialestimates. Finally, the results from each of the activitystudy areas provide valuable information regarding thedevelopment of a human MPD mission and the synergisticactivities required prior to undertaking such anexploration endeavor.

Human Exploration and Destination Drivers

Analyzing the Genotoxicity of Lunar Dust

Rachel Caston and Bruce Demple, Department of Pharmacological Sciences, School of Medicine, Stony Brook University, Stony Brook, NY 11794If we hope to return humans to the Moon for long-term exploration and science, the effects of exposure to lunar dust need to be considered. Lunar dust may be able to cause DNA damage via the production of free radicals (see abstract by Schoonen et al.). Unrepaired DNA damage disrupts cell function and can lead to mutational changes after DNA replication. Mutations can lead to effects of varying severity, such as enabling cancerous growth or neurodegenerative disorders.To study the biological effects of the dust, the lunar soil simulant JSC-1A was used with a mouse neuronal cell line in culture. The cells were challenged in two ways. In the first set of experiments, JSC-1A was added directly to cells in culture dishes. In the second approach, JSC-1A dust was first washed with water for 5 hours, and cells were then challenged with either the washed dust or the wash water separately. In this way, mechanical and chemical interactions can be analyzed individually. Cell viability was analyzed using a dye-exclusion assay. In the preliminary experiments, the cells treated with either the prewashed dust or with the water used for washing had a greater survival than cells treated with the dust directly. This implies that both mechanical and chemical interactions affect the cells, or that unstable toxic products are eliminated by this simple treatment.The next step will be to perform similar experiments accompanied by an assessment of DNA damage. DNA damage will be measured using the "LORD-Q assay", which employs the polymerase chain reaction. The assay depends on the ability of a DNA polymerase to copy lesion-containing DNA, which is then amplified in successive rounds of the chain reaction. If the polymerase encounters a blocking lesion while replicating the DNA of the sample, a lower amount of PCR product is generated. In this way, DNA damage in control and JSC-1A treated cells will be compared.

Author: WILLIAM FARRELL

ORAL

Human Exploration and Destination Drivers

Spacecraft-NEO water interaction during the Asteroid Redirect Mission (ARM)

In the asteroid redirect mission, a robotic spacecraft will collect a 5 to 7-m near-Earth object (small asteroid) and place it in orbit about the Moon. Subsequent manned sorties will then visit the asteroid in lunar orbit via the Orion spacecraft. However, any manned spacecraft will have its own water-rich exosphere, this water being outgassed from the spacecraft body and emitted directly via water dumps. This man-made exosphere will interact with the asteroid surface, possibly leading to the accumulation of contaminating water at cooler or shadowed locations on the body. In this presentation we consider the accumulation of spacecraft water emission at the asteroid. We will use the space shuttle water cloud examined in great detail in the mid-1980s as an analog. We will especially examine the water accumulation on the NEO as a function of assumed body temperature profiles. While a spacecraft-delivered contaminating water cloud might be considered a drawback, we suggest herein to use the water emission in a set of active experiments to gain new insight into the enigmatic water molecule-surface interactions that occur at the Moon and airless bodies. For example, past NLSI and SSERVI science studies suggests that defects can be sites for increased water adsorption. We thus suggest the astronauts can create a ‘defect garden’ that includes upturned asteroid soil, fractured soils (by astronaut impacts via hammer), and irradiated soils all designed to determine changes in in-situ surface water retention.

Author: JENNIFER HELDMANN
ORAL

Human Exploration and Destination Drivers

FINESSE: Field Investigations to Enable Solar System Science and Exploration

The FINESSE (Field Investigations to Enable Solar System Science and Exploration) team is focused on a science and exploration field-based research program aimed at generating strategic knowledge in preparation for the human and robotic exploration of the Moon, near-Earth asteroids (NEAs) and Phobos & Deimos. We infuse our science program with leading edge exploration concepts since "science enables exploration and exploration enables science." The primary research objectives of our Science and Exploration programs are as follows: 1) FINESSE Science: Understand the effects of volcanism and impacts as dominant planetary processes on the Moon, NEAs, and Phobos & Deimos.2) FINESSE Exploration: Understand which exploration concepts of operations (ConOps) and capabilities enable and enhance scientific return.To accomplish these objectives, we conduct an integrated research program focused on scientifically-driven field exploration. Our research is accomplished through a sequenced field program at two strategically chosen field sites. Fieldwork will be conducted at Craters of the Moon National Monument and Preserve in Idaho and at the West Clearwater Lake Impact Structure in northern Canada. These sites have been chosen to address scientific questions pertaining to volcanism and impact science, respectively, as geologic analogs to the SSERVI Target Bodies. These terrestrial volcanic and impact records remain invaluable for our understanding of these processes throughout our Solar System, since these are our primary source of first hand knowledge on volcanic landform formation and modification as well as the three-dimensional structural and lithological character of impact craters. Impact cratering, for example, is the dominant geological process on the Moon, asteroids, and moons of Mars. Our scientific objectives are to understand the origin and emplacement of impactites, the history of impact bombardment in the inner Solar System, the formation of complex impact craters, and the effects of shock on planetary materials. Volcanism is another dominant geologic process that has significantly shaped the surface of planetary bodies. We will study the processes, geomorphic features and rock types related to fissure eruptions, volcanic constructs, lava tubes, flows and pyroclastic deposits. We will conduct scientific fieldwork under simulated lunar, NEA, and Phobos & Deimos mission constraints to evaluate strategically selected ConOps and capabilities regarding their anticipated value for future human-robotic scientific exploration. Throughout this field program, the assessment of our ConOps and capabilities will focus on understanding how and if each element of our research architecture leads to an acceptable level of science return. Our assessments will be systematically conducted at increasing levels of detail using a variety of quantitative and qualitative evaluation methods. FINESSE is composed of a world-class team of scientists, robotics and exploration subject experts, astronauts and operations specialists. We also infuse a variety of Education and Public Outreach (E/PO) activities into this unique project to bring the excitement of this science and exploration work to a broader community.

Author: DANA HURLEY
ORAL

Human Exploration and Destination Drivers

Water as a resource for science and exploration on the Moon

Water ice has been mapped in the polar regions of the Moon and appears to have a heterogeneous distribution. Remote sensing data at IR and FUV wavelengths are consistent with frost covering up to a few percent of the surface. Meanwhile, neutron and radar data that probe greater depths are consistent with localized areas with higher bulk concentrations of water. The distribution of water in lunar polar dregions is controlled by processes of scientific interest, including: impact gardening; thermal diffusion; sputtering; and photolysis. Any mission that can quantify the heterogeneity will provide important insights into the relative importance of these processes, and further will enable relating the current contents to the initial contents. Complementarily, knowledge of the distribution of water is important for In Situ Resource Utilization (ISRU) because the heterogeneity and abundance will drive the design of its harvesting. Furthermore, it may be advantageous to identify the locations of enriched pockets of water for exploitation.We present a summary of the present knowledge of the distribution of water ice in permanently shadowed regions. Next we model the effect of impact gardening on the distribution of ice in the coldest regions where thermal processes are not dominant. Comparing the model to data, we place an estimated age on the lunar volatile deposits in permanently shadowed regions. In addition, the model results are interpreted in terms of how the heterogeneity should be expected to affect ISRU on the Moon. We present the trade space between mobility and accessibility of volatiles in the coldest regions of the Moon.

Author: JOSE HURTADO
POSTER

Human Exploration and Destination Drivers

Geologic Activities During Microgravity EVAs: Lessons Learned from DRATS 2011 and RATS 2012

The 2011 Desert RATS and the 2012 RATS tests investigated exploration of a Near Earth Asteroid (NEA). We report lessons learned regarding geologic activities performed during analog microgravity extravehicular activities (EVAs). The 2011 test in the San Francisco Volcanic Field, AZ, examined field geology operations in two EVA modes using: 1) “Super” SAFER (Simplified Aid For EVA Rescue), a notional, self-contained propulsive backpack; and 2) Astronaut Positioning System (APS), a passive “robotic” arm attached to a Space Exploration Vehicle (SEV). SSAFER operations allow crewmembers to conduct un-tethered EVAs but require anchoring for geologic tasks. APS operations allow EVA crewmembers to control their position on the arm, with the SEV responsible for station-keeping and translation to reach areas outside the APS radius. The 2012 tests were conducted at the NASA Johnson Space Center and included mission simulations utilizing: a) a virtual reality (VR) system linked to an SEV flight simulator; and b) the Active Response Gravity Offload System (ARGOS). Using the former, pairs of crewmembers explored a VR model of asteroid Itokawa in two modes: 1) SSAFER EVAs with the piloted SEV supporting at a standoff distance; and 2) APS EVAs with the SEV maneuvering close to the target surface. ARGOS microgravity EVAs focused on sample collection and mobility tasks around analog target surfaces using a combination of tethers, APS, and various geologic tools. Results of the 2011-2012 activities led to the following conclusions. 1) High-fidelity science and engineering field-tests like DRATS 2011 require well-constrained assumptions about microgravity operations, e.g. time and resource (metabolic, propellant, etc.) expenditures required to complete EVA tasks. 2) Simulations like the 2012 RATS tests are important precursors to field tests to determine those constraints. Some issues, such as the need to account for propellant use and anchoring for SSAFER operations, were considered for the 2011 test but not quantified until the 2012 tests. Others became clear after the 2012 ARGOS work, including limitations imposed by microgravity on: translation across complex/hazardous terrain; use of tethers vs. APS & SEV vs. SSAFER for mobility/anchoring/station-keeping; manipulation of geologic tools and materials; and execution of geologic tasks. These will affect EVA timelines, influence traverse planning, and impact the design of equipment for field-tests and real missions. 3) Within the context of the microgravity environment and mission constraints, there are best practices for SSAFER- vs. APS-aided EVAs. Both the 2011 and 2012 experiences are critical for understanding the applicability of these operational modes. 4) High-fidelity VR simulations illustrate challenges that are not apparent in the field, e.g. the demands of piloting the SEV while simultaneously supporting the EVA crewmember. Similarly, although low-fidelity microgravity analogs, field-tests are crucial for investigating crew resource management and testing equipment and procedures in ways possible only in a high-fidelity science context. 5) Therefore, analog tests in support of human exploration of planetary bodies should include integrated field and laboratory (e.g. VR, ARGOS, Neutral Buoyancy Laboratory, etc.) simulations.

SSERVI-ESF14-135

Author: TELANA JACKSON

POSTER

Human Exploration and Destination Drivers

Astronaut Charging On an Asteroid

The plasma environment about a small near-Earth object is very complex, ranging from an electron-rich photoelectric sheath on the dayside to a very low density plasma wake region on the nightside. As a consequence, the surface potential can range from a few volts positive on the dayside to large negative values in shadowed regions. An astronaut as an isolated object in the solar wind plasma will also have his/her own electrical potential. Further, when electrically tethered to a larger spacecraft, the astronaut will be electrically connected to the ground of the spacecraft that likely floats to a positive potential (due to spacecraft photoelectron emission) relative to the plasma. The objective of this work is to consider the optimal location for an astronaut to make electrical 'first contact' with the asteroid, given the complex surface potential structure of the object from sunlight to shadowed locations. We consider cases where the astronaut is 1) isolated and immersed in the local plasma, 2) isolated and immersed in the local plasma but also developing a charge due to contact electrification, and 3) tethered back to the spacecraft and grounded to the potential of the spacecraft. In essence, we ask where is the safest place to make contact in order to minimize differential charging? We also consider the effect the spacecraft outgassing (and new ions) have on the environment and potential differences. We develop and present a set of recommendations on the remediation of the hazards associated with object-to-object electrical interactions.

Author: DAVID KRING
ORAL

Human Exploration and Destination Drivers

Implementing the GER: Human-assisted Lunar Sample Return from the Schrödinger and South Pole-Aitken Basins Using the Orion Spacecraft

The Global Exploration Roadmap (GER) outlines a series of lunar vicinity missions that include the Space Launch System (SLS) and the Orion spacecraft. Orion is being prepared for an Exploration Flight Test (EFT)-1 on a Delta IV in December 2014, followed by Exploration Mission One (EM-1) on the SLS in 2017, the latter of which is an un-crewed flight to a distant retrograde orbit around the Moon. EM-2 follows in 2021 with a crewed lunar orbit-capable system. With that orbital capability, astronauts could interact with a robotic asset on the lunar surface to facilitate sample return. Indeed, the GER anticipates human-assisted sample return within the decade and humans to the lunar surface are scheduled about four years later. A multi-year Global Lunar Landing Site Study to Provide the Scientific Context for Exploration of the Moon (Kring and Durda (eds.), 2012, LPI Contribution No. 1694) found that the Schrödinger and South Pole-Aitken basins are two high-priority targets. To adequately address both scientific and exploration objectives, sample return missions are required. The best results would be obtained by a trained crew on the lunar surface, but a productive iterative step would be to deploy a robotic asset to the lunar surface that is coordinated with an Orion flight. One of several potential landing sites within the Schrödinger basin would provide access to a pyroclastic deposit with ISRU potential and impact-generated lithologies that can help test the lunar cataclysm hypothesis and lunar magma ocean hypothesis.In a human-assisted sample return mission, astronauts on NASA's Orion vehicle and ESA's service module could be sent to an orbit around the Earth-Moon L2 point ~60,000 km above the lunar far side surface or to a distant retrograde orbit (DRO) that also passes over the far side surface. Currently, the target DRO passes ~70,000 km above the lunar far side. In parallel, a robotic asset could land within the Schrödinger and/or South Pole-Aitken basins and collect samples for return to Earth. A lander and rover could maintain contact with Earth through Orion. Moreover, astronauts on Orion could teleoperate the rover to reduce mission risk, enhance scientific return, and test operational concepts for future missions, including those needed to execute a Mars exploration program. An ascent vehicle on the robotic asset could return samples to the Orion vehicle for return to Earth or, with the addition of a capsule, directly to Earth. Our studies of mission operation time lines indicate Orion would have 20 and 10 days of communication with the surface asset from an L2 orbit or DRO orbit, respectively, while accommodating ascent vehicle rendezvous for sample transfer to Orion with a total mission duration of about a month.

Author: SAMUEL LAWRENCE

ORAL

Human Exploration and Destination Drivers

High-Priority Destinations for Lunar Exploration

A systematic program of human and robotic lunar exploration will greatly advance all planetary science and exploration objectives [1]. Precursor campaigns should include rovers, sample return, and ISRU demonstrations preparing for human missions[2]. LRO produces data essential for scientific exploration [3-6] and informing mission design [7-9]. Site assessment is critical to determine optimal precursor mission strategies, particularly sample returns. Sample return addresses : 1) Magmatic evolution of the Moon, 2) volcanic processes, 3) time-stratigraphic relationships, and 4)resource potential. Interior Evolution: Sample return of materials from Hansteen Alpha, Lassell Massif, Gruthuisen Domes, and/or Mairan T enables understanding the composition and emplacement style of these silicic volcanic constructs [10-14].Volcanic Processes: Sample return from low mare shields could determine compositional or other differences between low shields and plains-type mare basalts [15-17]. Candidates include Marius Hills, Hortensius Domes, and the Isis/Osiris cones. Time-Stratigraphy: Establishing precise ages for recent lunar geologic events calibrates cratering statistics that are applied to other terrestrial planets [e.g., 18,19]. The youngest (~1 Ga) Procellarum basalts [20] and Copernicus crater are ideal locations to age-date geologically recent events.Resource Potential: Regional pyroclastic deposits Aristarchus and Sulpicius Gallus are excellent locations to assess the properties and compositions of these resources [21,22]. Pyroclastic samples would enable qualification of ISRU hardware, expanding the capability and reducing the costs of Solar System exploration. References: [1] NRC (2007) SCEM Report [2] Lunar Exploration Roadmap [3] Robinson M. et al. (2011) LPI 1646, 72 [4] S. Lawrence et al. (2010) LPI 1595, Abs. 35. [5] J. Gruener et al. (2009 AGU 31, 0010. [6] M. S. Robinson et al. (2010) SSR 150, 1–4, pp. 81–124. [7] E. J. Speyerer and M. S. Robinson (2013) Icarus, 222, 1, pp. 122–136. [8] J. E. Gruener and B. K. Joosten (2009) LPI 1483 pp. 50–51. [9] E. J. Speyerer et al. (2013) LPSC 44, 1745. [10] T. D. Glotch et al. (2010) Science, 329, 5998, pp. 1510–1513. [11] B. T. Greenhagen et al. (2010) Science, 329, 5998, pp. 1507–1509. [12] B. L. Jolliff et al. (2011) Nat. Geosci, 4, 8, pp. 566–571. [13] B. R. Hawke et al. (2003) JGR 108, p. 8.[14] J. W. Ashley et al. (2013), LPSC 44, Abstract 2504. [15] S. J. Lawrence et al. (2013) JGR, doi:10.1002/jgre.20060. [16] J. B. Plescia, (2013) 2013 NASA Lunar Science Forum. [17] P. D. Spudis et al. (2013) JGR, doi:10.1002/jgre.20059 [18] H. Hiesinger et al. (2011) GSASP 477, pp. 1–51. [19] D. Stöffler and G. Ryder (2001) SSR 96, pp. 9–54. [20] S. J. Lawrence et al. (2011) LPI 1611, 5047. [21] B. R. Hawke et al. (1990) Proc LPSC 20 pp. 249–258. [22] B. R. Hawke et al. (1991) Proc. LPSC 21 pp. 377–389.

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Author: DARLENE LIM

ORAL

Human Exploration and Destination Drivers

Managing, mitigating and adapting to the impact of communication latencies on human-robotic scientific exploration – lessons from Pavilion Lake Research Project field deployments.

Regardless of when humans ultimately venture beyond Low Earth Orbit, and regardless of where we explore, there will be certain operational, technical and scientific parameters that will cross-cut the exploration architecture. Communications, and specifically the design principles and operational methodologies required to manage unavoidable time-delayed communications during human scientific exploration, will be critical to our future successes in human space flight as we explore at increasing distances from earth. Given that science will undoubtedly be a key driver in future human exploration of the Moon, NEAs and beyond, the effects of time-delayed communications on science, science operations and productivity, mission operations and technological management require focused examination as these effects are not yet understood. Here we present results and lessons learnt from a real (non-simulated) field science program within which simulated time-delayed communications experiments were performed to assess the impact of these latencies on scientifically driven exploration. This research was aimed at measuring the impact of lunar-like, and NEA communications delays on both scientific productivity and human factors, such as workload, during our real science operations. We also examined the capabilities, operations concepts and communications protocols required to manage tethered Science Divers, Surface Support Crews, and a distributed Science Backroom Team. Our research was conducted during the 2011 and 2014 Pavilion Lake Research Project (PLRP) field deployments to Kelly and Pavilion lakes in British Columbia, Canada. The field activities involved a mix of DeepWorker submersibles, SCUBA divers, and Remotely Operated Vehicles (ROVs), which were used to study microbialite morphogenesis in Pavilion and Kelly lakes, and the potential for biosignature preservation in these carbonate rocks. Further background on the field deployment activities will also be presented.

Author: CLIVE NEAL

ORAL

Human Exploration and Destination Drivers

Developing the "Lunar Vicinity" Scenario of the Global Exploration Roadmap

The Global Exploration Roadmap (GER, [1]) has been developed by the International Space Exploration Coordination Group (ISECG – comprised of 14 space agencies) to define various pathways to get humans beyond low Earth orbit and eventually to Mars. Such pathways include visiting asteroids or the Moon before going on to Mars. This document has been written at a very high level and many details are still to be determined.In this presentation, we develop the GER "Lunar Vicinity" scenario by mapping a number of relevant reports/documents into the GER. These are in no way meant to encompass everything that is relevant to this process (others should be added – e.g., the soon to be published JAXA Space Exploration Roadmap). This exercise is intended to demonstrate that existing documents can be mapped into the GER despite the major differences in granularity, and that this mapping is a way to promote broader national and international buy-in to the GER.The Global Exploration Roadmap: The common goals are as follows: •Develop Exploration Technologies & Capabilities.•Engage the Public in Exploration.•Enhance Earth Safety. •Extend Human Presence.•Perform Science to Enable Human Exploration.•Perform Space, Earth, and Applied Science.•Search for Life.•Stimulate Economic Expansion.With Mars being the goal there are three paths articulated - Exploration of a Near-Earth asteroid; Extended Duration Crew Missions; and Humans to the Lunar Surface. The GER gives 5 goals for the Lunar Surface scenario:•Technology test bed (surface power systems, long distance mobility concepts, human-robotic partnerships, precision landing).•Characterizing human health and performance outside Earth's magnetosphere and in a reduced gravity environment.•Conducting high priority science benefiting from human presence, including human-assisted lunar sample return. •Advance knowledge base related to use of lunar resources.•Explore landing sites of interest for extended durations.The Mapping Process: documents highlighted here are as references [2-9]. Other documents will be added to this list prior to the presentation.References: [1] Global Exploration Roadmap (2013) http://www.globalspaceexploration.org, [2] Ehrenfreund et al. (2012) ASR 49, 2-48. [3] SKGs for the "Moon First" Human Exploration Scenario (2012) http://www.lpi.usra.edu/leag/GAP_SAT_03_09_12.pdf [4] LER (2013) http://www.lpi.usra.edu/leag/ler_draft.shtml [5] NRC (2007) http://www.nap.edu/catalog/11954.html [6] Crawford et al. (2012) Planet. Space Sci. 74, 3-14. [7] Crawford (2010) Astrobiology 10, 577-587. [8] Lunar Science Workshop (2007) NASA Advisory Council Wksp Science Associated with the Lunar Exploration Architecture. http://www.lpi.usra.edu/ meetings/LEA/finalReport.pdf [9] NASA's Strategic Direction (2012) http://www.nap.edu/catalog.php?record_id=18248

Author: CLIVE NEAL

ORAL

Human Exploration and Destination Drivers

Using the Moon to go to Mars: Why Lunar Exploration Should Not be Ignored

The Lunar Exploration Analysis Group (LEAG) was tasked by the NASA Advisory Council in 2007 to developed a comprehensive Lunar Exploration Roadmap (LER; [1]) as part of the Vision for Space Exploration. The LER is comprised of three themes: Science, Feed Forward, and Sustainability. It is the Feed Forward theme that is the subject of this presentation.The purpose of the Feed Forward theme is to establish mission risk reduction technologies, systems, and operational techniques that could be developed through a lunar exploration program using 2 criteria: Mars/Small Body Risk Reduction Value: How well do the candidates address the key risk reduction areas identified through NASA's robotic and human Mars/Small Body mission planning studies; and, Lunar Platform Value: Do candidates leverage the unique attributes of a lunar program to achieve success – or – would other platforms be more effective from a technical/cost perspective. There are two goals under this theme that are focused on Mars (with the third focused on asteroids): Goal FF-A addresses hardware (Identify and test technologies on the Moon to enable robotic and human solar system science and exploration); Goal FF-B addresses operations (Use the Moon as a test-bed for missions operations and exploration techniques to reduce the risks and increase the productivity of future missions to Mars and beyond).The LER presents a foundation upon which to develop a long-term plan that will enable humans to explore Mars. The Moon's vicinity and environment make it the logical place to retire risk through the development of systems and operations for human activities off planet. Having the Moon in the critical path to Mars has a number of important and critical advantages that are focused on the low gravity lunar environment, as well as the Moon's close proximity to Earth:•Testing bioregenerative technologies that are needed to support wastewater processing, air revitalization and food production.•Perform long-duration testing of an integrated surface life support system that is needed to simulate Mars surface stay times exceeding 500 days.•Testing countermeasure technologies that need to be tested so as to assure human performance remains at an acceptable standard.•Testing surface mobility systems (range, duration, terrain, time).•Testing surface fission power system technologies that should be capable of being autonomously deployed and able to initiate/sustain power generation without human interaction.•Testing monolithic habitat technologies on the lunar surface that incorporate the capability for autonomous deployment and operations without human intervention.•Testing radiation shielding technologies outside of the Earth's magnetosphere.•Testing dust mitigation technologies to prevent dust from interfering with mechanical systems and causing health problems for astronaut crews.•Testing forward and backward planetary protection technologies to prepare for human and robotic operations on Mars.•Conduct a Mars surface mission simulation on the Moon.•Develop cost effective surface systems that can be developed in a relatively short period of time.[1] Lunar Exploration Roadmap (2013) http:// www.lpi.usra.edu/leag/ler_draft.shtml

Author: LILLIAN OSTRACH

ORAL

Human Exploration and Destination Drivers

Characterization of Smooth Deposits Within South-Pole Aitken Basin: The Search for Impact Melt Deposits

Recent lunar missions, including the Lunar Reconnaissance Orbiter (LRO), Chandryaan-1, Kaguya/SELENE, and the Gravity Recovery and Interior Laboratory (GRAIL), enable researchers to answer outstanding questions critical to lunar science in preparation for future robotic and human exploration. The South Pole-Aitken basin (SPA) is identified as one of the highest-priority targets for future exploration and sample return because multiple science objectives can be addressed, including investigations related to the bombardment history of the Solar System, the lunar interior (including crustal structure and mantle composition), and the volcanic evolution of the Moon [1,2]. Impact melts form during the impact process; radiometric ages for melts therefore date an impact event. Although SPA is heavily modified by subsequent basin, crater, and mare materials, by identifying the oldest surfaces from remote sensing data, it may be possible date the SPA event (and those impact basins located within SPA) via a future sample return mission (e.g., MoonRise). Previous investigations employed multiple techniques and datasets [e.g.,3-6], and we build upon these findings to further characterize geology within SPA. Our efforts place particular emphasis on smooth deposits interpreted to be impact melt or basin ejecta interior to and surrounding “young” impact craters (e.g., Alder, Bhabha, Bose, Finsen), although we do include mare and cryptomare deposits in our survey. Our primary objectives are to (1) determine smooth deposit origin on the basis of albedo, composition, embayment relations, and stratigraphic relations to crater ejecta, (2) determine the relative ages of both the smooth deposit and its associated crater, placing the unit into stratigraphic context with other SPA basin materials, and (3) identify locations hosting the oldest surfaces (presumed to be SPA-derived impact melt) in SPA. In a comprehensive mapping effort to better understand the geology of the SPA basin using new remote sensing data, we utilize multiple datasets (e.g., LRO, M3) at high resolution to characterize geologic units on the basis on morphology (e.g, degradation state, stratigraphic relations), composition, and in some cases, crater densities [7]. [1]Committee on the Scientific Context for Exploration of the Moon National Research Council (2007), “The Scientific Context for Exploration of the Moon: Final Report”, National Academies Press.[2]Committee on the Planetary Science Decadal Survey (2011) “Vision and Voyages for Planetary Science in the Decade 2013-2022”, National Academies Press.[3]Wilhelms, D. (1987) The Geologic History of the Moon, USGS Prof. Pap. 1348.[4]Pieters, C.M. et al. (2001) JGR 106, 28001-28022.[5]Petro, N.E., Pieters, C.M. (2004) JGR 109, E06004.[6]Moriarty et al. (2013) JGR Planets 118, 2310-2322.[7]Kirchoff, M.R. et al. (2013) Icarus 225, 325-341.

Author: MARGARET RACE

Human Exploration and Destination Drivers

ORAL

Planetary Protection For Future Human Missions -- Addressing Science Gaps And Providing Input For Future Systems, Operations And Equipment For Mars

COSPAR planetary protection (PP) principles and implementation guidelines for human Mars missions require protection of Mars from forward contamination during operations and exploration, protection of astronaut health and safety throughout the long duration mission, and safeguarding of Earth from back contamination upon return. Engineers and scientists have begun to analyze how these requirements will constrain the diverse systems, operations and equipment necessary for future missions While experiences from ISS and other activities in Earth orbit provide a strong foundation for planning human missions back to planetary surfaces (the first time since the Apollo program), planetary protection requirements for introduce an assortment of new challenges and data gaps, particularly due to recent new understanding about microbial life and environmental conditions on potentially habitable solar system bodies, like Mars. A number of recent NASA and international workshops and studies have identified particular concerns associated with planetary protection needs, including information associated with human health and life sup-port requirements; EVA, surface operations, contami-nation mitigation methods; plans for in situ resource utilization (ISRU); equipment and procedures for science exploration, sample collection and handling; and quarantine methods, containment, and systems intended to avoid back contamination of Earth. In some cases, these concerns overlap with areas of active science investigations. It is clear that additional science research will be essential for narrowing knowledge gaps and contributing to productive human missions that maximize science return. Important information can be collected during robotic precursor missions, in labs or analogue sites on Earth, and through research and experiments on ISS. Presumably less restricted missions to asteroids can also be used for gathering data or testing feed-forward concepts associated with planetary protection. This presentation summarizes recent information under discussion by NASA and international groups about science and technology needs for meeting PP constraints on future human missions, particularly to Mars. Precursor science data will be important not only preliminary mission planning, but also as input for the upcoming NASA process for drafting a Planetary Protection Procedural Instruction (NPI) for Hu-man Extraterrestrial Missions . Among the key science research areas identified are those that increase information on survival of spacecraft and human associated terrestrial organisms and their molecular components in ambient martian environments; information on sterilization and monitoring capabilities for wastes material and mission-associated equipment and samples; information on distribution of water on Mars, at both the macro- and micro-scales, both near-surface and deeper; and information on near- and far-field contamination transport. Filling strategic science gaps with focused investigations will be important for eventual mission designs and operations, particularly those that control, mitigate or eliminate risks associated with biological contamination.

Author: MARGARET RACE
ORAL

Human Exploration and Destination Drivers

Lunar Environmental Management: What's Needed to Guide Future

With increased interest in exploration and use of outer space beyond LEO, it is clear that the international community will soon need to address questions about the future activities of multiple stakeholders on the surfaces of the Moon and other celestial bodies and the potential conflicts of uses that may arise—some of which are very different than experiences on Earth and in Earth orbit. Under the Outer Space Treaty, there are clear policies and regulations regarding planetary protection during exploration, but currently no standardized guidelines for environmental management, stewardship or responsible use on planetary surfaces. While recent NASA guidelines to preserve the Apollo landing sites are an example of an incremental approach to addressing concerns about disruption, it may also be helpful to develop a more generic approach to concerns about uses and disruptions of planetary surfaces. As a first step towards framing generic guidelines for exploitative and other activities on planetary surfaces, there is a need to understand what kinds of activities will be involved, what types and scales of disturbances are likely to occur in the near- and longer-terms, and whether potential impacts are likely to be transient, cumulative or irreversible. Such information will be essential for the eventual drafting of protocols to identify and protect important resources— environmental, as well as historical, scientific or 'other' features of interest to humans. This presentation provides information on a preliminary study to categorize the nature and extent of proposed lunar exploration and exploitation activities in the coming decades and to construct a draft matrix and framework for considering how to balance stakeholders interests in exploring and using space resources. Such an approach could be helpful in examining the types of impacts or disruptions that might be important in different time frames, from pilot projects through scale up operation, on various planetary bodies with different characteristics.

Author: MARK ROBINSON

Human Exploration and Destination Drivers

ORAL

Discoveries from the Lunar Reconnaissance Orbiter and Future Human Exploration of the Moon

Measurements from the Lunar Reconnaissance Orbiter (LRO) are providing answers to old questions, calling into question currently held beliefs, and raising new questions both in terms of science and exploration. Globally distributed meter-scale LROC images revealed a large population of young compressional scarps that were likely formed as molten portions of the core transitioned to solid, resulting in a negative volume change that put the brittle crust into a compressional state. These features are so young that is likely, if not certain, that large moonquake driven surface deformation occurs in the present era. Rather than clarifying the relative ages of late Copernican craters, LROC images call into question the relative significance of primary, secondary, and auto-secondary impacts and the effect of target strength (impact melt rocks, granular ejecta) on the cratering record. LROC images revealed over 75 occurrences of small (<5 km) young volcanic extrusions with ages proposed to be <200 my. Analysis of observations from LROC and Diviner revealed a previously unknown farside silicic volcanic center between Compton and Belkovich craters, far from any previously known domes or red spots. The age of this center is difficult to determine with accuracy due to its size and probable resurfacing events (pyroclastic?). Similar observations of the Lassell massif also raise the possibility of silicic explosive activity. Like its farside counterpart the age of terminal volcanic activity at Lassell is ambiguous. LROC observations led workers to question the current stratigraphic relations of touchstone basin-forming events (Imbrium, Serenitatis, Crisium), and thus the body of evidence for the late heavy bombardment. Observations with nearly every instrument onboard LRO show the poles to more enigmatic than previously thought. For the same crater some measurements indicate significant H deposits while others show no enrichment. Likely this conundrum is the result of depth sensitivity of the various measurements and a complex movement of volatile species within the regolith. Preparing for a human return to the Moon requires an exploration strategy to investigate key resource, engineering, and science questions. Precursor missions include polar landers with mobility to investigate distribution of volatiles. Simple yet capable long-lived rovers to measure, sample, and scout major geologic terrains. Sample return is required to test current hypotheses and calibrate the relative cratering record. These robotic missions feed into the decision process for selecting crewed targets, deliver samples to human exploration sites, and test technologies for missions to Mars. Early crewed missions will provide the means to unravel complicated geologic problems (i.e. complex silicic volcanism), test and implement resource utilization strategies, and provide the experience base to live and work on another planet. An exploration strategy of this scale is best carried out through close international cooperation implementing a sustainable plan robust to political winds.

Author: BRIAN SHIRO

ORAL

Human Exploration and Destination Drivers

Geological Field Activities at the HI-SEAS Planetary Surface Analog Mission Simulation in Hawaiʻi

The Hawaiʽi Space Exploration Analog and Simulation (HI-SEAS.org) program studies team function and performance on long duration exploration missions conducted in a remote habitat located on Mauna Loa, Hawaiʽi. The basaltic terrain and sparse vegetation of the site make it a good geologic analog to the Moon or Mars, and since the site is accessible year-round, it allows for longer-term isolation studies than other analog locations. HI-SEAS missions are comprised of six crewmembers who live in the habitat and interact with a mission support team remotely via an imposed 20-minute communications delay to provide Mars-like operational latencies. After a successful first mission lasting four months in 2013, NASA awarded HI-SEAS three years of additional funding to explore themes surrounding crew autonomy on missions of increasingly longer durations up to twelve months. The second four-month mission began on 28 March 2014.HI-SEAS crewmembers spend their time taking part in a number of research studies. Some of these activities require them to leave the habitat and conduct pedestrian extra-vehicular activities (EVAs) while wearing simulated space suits to approximate the encumbrances astronauts would face while conducting such excursions. One goal of HI-SEAS is to compare crew performance as missions increase in length, and to meet this objective a team of geologists works with a team of psychologists to develop geology-related tasks for the crew to complete in the area surrounding the habitat. The team-oriented tasks are designed to be gradable with quantifiable metrics so that meaningful conclusions about crew performance can be assessed.The tasks, which are given in the context of resource exploration and environment characterization, are presented in a progressive fashion so that each activity builds upon the previous one. First, features or areas of interest are identified in aerial imagery. The crew is then asked to scout these features on the ground and characterize their properties. This could take the form of measuring dimensions of a skylight, mapping flow units, collecting rock samples, or analyzing the samples using equipment in the habitat's laboratory. The HI-SEAS geology team evaluates how accurately the crew is able to accomplish these tasks compared with known values.

Author: BRIAN SHIRO

ORAL

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Author: STELLA TSIRKA
POSTER

Human Exploration and Destination Drivers

Lung tissue exposure to Lunar Simulants

Lung tissue exposure to Lunar Simulants1Jillian C. Nissen, 2Martin A. Schoonen, 1Stella E. TsirkaRIS4E, Stony Brook University, 1Departments of Pharmacological Sciences, 2Geosciences, Environmental and Climate Sciences, Brookhaven National Lab.Future astronauts will be exposed to harsh environments with potentially harmful but unknown health effects. While some studies have been conducted on lunar materials, they failed to capture the full complexity of materials found on the moon. Lunar dust is extremely dry, exposed to space radiation and micrometeorite impacts, and can alter the surface of the material to result in greater reactivity in the lungs. Utilizing a set of materials that match not only the chemical composition of lunar dust, but also have been exposed to conditions similar to the space environment, we examine the effects of exposure of these samples on lung tissue. Utilizing ex vivo mouse lung organotypic slices, which accurately recapitulate not only the cell types present in the lung but also their tissue ratios and three-dimensional architecture, we assess changes in inflammatory markers, cell death, and reactive oxygen species generation through immunohistological and biochemical approaches. Control soils we have reported in the past are used as positive and negative controls.

Author: KELSEY YOUNG
ORAL

Human Exploration and Destination Drivers

Incorporating Handheld Technology into Planetary Surface Exploration: Ongoing Testing and Further Studies

The next generation of planetary surface exploration will include the need for collecting valuable and diverse samples for return to Earth. While advanced traverse planning is crucial to mission success, the community must also work to develop a suite of in situ geochemical technologies for use in real-time sample high grading. One such instrument is the handheld x-ray fluorescence spectrometer (hXRF). Initially developed for use in industry and mining by companies such as Bruker, ThermoScientific, and Innov-X, we have subsequently tested this technology on a well-characterized suite of terrestrial geological samples in order to assess data return (data accuracy, precision and utility) and controlled field operations. Previous tests of this instrument also included testing on 18 lunar samples returned from the Apollo missions in order to investigate whether accurate and interpretable semi-quantitative data could be collected on the geochemically-complex lunar samples. While the initial instrument calibrations have been successful in proving the instrument's utility in unraveling the geochemistry of laboratory samples, the ultimate testing ground is deploying the hXRF in the field, preferably at a terrestrial analog site, in order to investigate the data quality of analyses completed in the field, and the utility of those data for understanding the geological history of the region or determining high priority samples for further study.Some initial field investigations were conducted in conjunction with the NASA Desert Research and Technology Studies (D-RATS) field tests. Manned crews traversed the San Francisco Volcanic Field, AZ, in habitat rovers designed to support their crews for multi-day geologic traverses. The crews collected samples from multiple lava flows in an effort to understand the eruptive history of the volcanic terrain. The hXRF has since been deployed on these samples and this instrument was able to differentiate between flows at a resolution not identified in the field by the crews. These results indicate that the hXRF could be a valuable addition to future planetary surface missions by providing increased contextual awareness of the field site. These studies also indicate a need for future development and testing of technologies like the hXRF in an effort to investigate critical features for a suite of instrumentation that would be deployed for characterization of SSERVI Target Bodies. In addition to technology selection and implementation, it is important to understand operational factors of such instruments and how the data will be presented and used by a human crew, a study goal that will be addressed by the SSERVI Remote, In Situ, and Synchrotron Studies for Science and Exploration (RIS4E) team.The RIS4E team plans to investigate instruments similar to the hXRF in geologic field investigations to quantitatively assess factors impacting data quality, field operations, and how the data are applied during mission operations. The field site where this instrumentation will be deployed is the December 1974 flow in Kilauea Volcano, HI. The RIS4E team seeks to constrain the variability of geochemistry and mineralogy across the field site using a suite of portable instrumentation.

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Author: KELSEY YOUNG

ORAL

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